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*Completion of One Year Biventing Tests...*  
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*2 Feb 95*

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DEPARTMENT OF THE AIR FORCE  
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE  
BROOKS AIR FORCE BASE TEXAS

2 Feb 95

MEMORANDUM FOR 15 CES/CEV  
ATTN: Mr. Bill Barry  
75 H Street  
Hickam AFB HI 96853-5233

FROM: HQ AFCEE/ERT  
8001 Arnold Drive  
Brooks AFB TX 78235-5357

SUBJECT: Completion of One Year Bioventing Tests: Area H; Area K; and Waikakalaua Fuel Storage Annex

The Air Force Center for Environmental Excellence (AFCEE) one-year bioventing test and evaluation projects at the above sites have been completed. Figure 1 provides general site information and Table 1 provides a summary of initial, six-month, and one-year fuel biodegradation rates measured at several monitoring points. Table 2 provides a summary of initial and final soil and soil gas sampling results for total recoverable petroleum hydrocarbons (TRPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). Based on results from your site and 120 other sites currently under operation, bioventing is cost-effectively remediating fuel contamination in a reasonable time frame. We recommend its application in areas within the above sites where contamination is present in vadose zone soils and at other sites on your installation using the criteria in the AFCEE Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, May 1992, including Addendum One, February 1994. These are found in the "Tool Box" recently sent to your base.

As you are aware, the bioslurper technology is aimed at light nonaqueous phase liquid (LNAPL) free product recovery while simultaneously bioventing contaminated vadose zone soils through vapor extraction. Thus, the current bioventing trials establish that soil remediation can be enhanced through soil aeration (bioventing) and the planned bioslurper trial will establish the applicability of bioslurping. In summary, bioslurping should be pilot tested and implemented, if appropriate, in areas of significant LNAPL free product. Bioventing alone should be reserved for those areas where the contamination is primarily in the form of vadose zone contamination. The use of bioventing is justified by the fact that increased hydrocarbon degradation (oxygen utilization) was exhibited in all monitoring points where significant soil contamination was detected.

The objective of the one year sampling effort was not to collect the large number of samples required for statistical significance. It was conducted to give a qualitative indication of changes in contaminant mass across the 125 bioventing sites within the Bioventing Initiative. Soil gas samples are somewhat similar to composite samples in that they are collected over a wider area. Thus, they provide a good indication of changes in soil gas profiles and volatile contaminant mass (See Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential, February 1994). Soil samples, on the other hand, are discrete point samples subject to large variabilities over small distances/soil types. Given this variability, coupled with known sampling and analytical variabilities, a large number of samples would have



AQ M01-02-0374

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**Print or Type Name**Laura Peña**Signature**Laura Peña**Telephone**210-536-1431

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to be collected to conclusively determine "real" changes in soil contamination. Because of the limited number of samples, these results should not be viewed as conclusive indicators of bioventing progress or evidence of the success or failure of this technology. In situ respiration tests are considered to be better indicators of hydrocarbon remediation than limited soil sampling.

It would appear the majority of the mass of contamination at Areas H and K resides as a LNAPL free product layer floating on the water table. Vadose zone soil samples (Table 2) do not display high concentration of fuel constituents. Area H displays measurable BTEX concentrations and high soil gas in the vent well. At Area H, it would appear that we were not "lucky" enough to sample in an area that is contaminated. The high soil gas readings in Areas H and K vent wells, as well as in Area K Monitoring Points (MP) A-5 and MPC-5, are consistent with the presence of LNAPL free product on the water table, and indicate that the contamination is primarily limited to the capillary fringe.

Area K exhibited significant oxygen utilization/ hydrocarbon biodegradation rates; whereas Area H did not display significant oxygen utilization/ hydrocarbon biodegradation, as we would have expected. This raises a question as to whether there is some source of inhibition of biological activity at Area H, like high lead residual from the aviation fuel. A respiration test within a discrete area of vadose zone soil contamination would provide a more conclusive answer as to whether there is any apparent inhibition. AFCEE/ERT will attempt to incorporate this testing into the bioslurper pilot test. Therefore, after the bioslurper pilot extraction well is selected, we will attempt to locate a vadose zone soil horizon with confirmed contamination and conduct a respiration test. Existing soil lead data from areas in close proximity to existing bioventing monitoring points should be extracted and reviewed for elevated levels.

The Waikakalaua Fuel Storage Annex displays more vadose zone soil contamination and overall soil gas is higher where soil contamination is detected.

Concentration changes appear to be consistent with the expected variability in soil/contaminant distributions. However, a more consistent trend is the decrease in BTEX concentrations in the majority of soil or soil gas samples. This indicates that the more readily biodegradable, yet most toxic and mobile, BTEX fraction is reduced significantly.

Sampling results indicate that a significant reduction in BTEX has taken place in the soils within the estimated 30-foot treatment radius of the pilot vent wells. Due to the inherent variability of in-situ soil samples, TRPH sampling is inclusive at this time, but all other measurements indicate that fuel biodegradation is progressing at a significant rate at Waikakalaua Fuel Storage Annex and Area K. AFCEE recommends that the bioventing pilot system continue to operate while planning for an expansion of the system for full-scale remediation which should focus on LNAPL free product recovery (bioslurping) at Areas H and K. The evaluation of full-scale remediation should include the conduct of the planned bioslurper pilot test so that the feasibility of free product recovery can be determined with an acceptable degree of certainty. Bioventing at other contaminated areas of Waikakalaua Fuel Storage Annex appears very promising. During system installations, initial soil gas surveys and respiration tests can be used to confirm the applicability of bioventing. System expansion to a full-scale bioventing and/or bioslurping can be arranged through AFCEE. Please contact Patrick E. Haas, AFCEE/ERT, DSN 240-4314 or commercial 210-536-4314, to discuss technical options for bioslurper pilot testing and full-scale expansion.

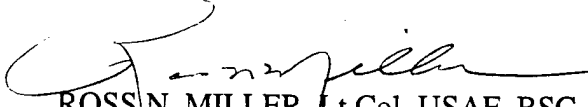
Data from your base and many others indicate that BTEX compounds are preferentially biodegraded over TPH. Since BTEX compounds represent the most toxic and mobile fuel constituents, a BTEX standard is a risk-based standard. We strongly encourage its use over an arbitrary TPH standard. Within the AFCEE Risk-based Petroleum Hydrocarbon "Tool Box," the report entitled "Using Risk-based Standards will Shorten Cleanup Time at Petroleum Contaminated Sites" summarizes the BTEX/TPH issue and will assist you in negotiating for a BTEX cleanup standard. Our information indicates that Hawaii currently regulates to a BTEX standard and not a TPH standard since there is no water quality standard for TPH. Hawaii also lists guidelines for polycyclic aromatic hydrocarbon constituent of fuels. However, these compounds are relatively immobile and therefore do not drive risk because there is usually no reasonable pathway of exposure. In conclusion, a risk-based approach will expedite site closure while reducing overall costs. Please contact Patrick E. Haas for details.

In general, quantitative destruction of BTEX will occur over a 1- to 2-year bioventing period. Soil gas surveys and respiration tests can be used as BTEX destruction indicators. If a non-risk-based/TPH cleanup is chosen, the pilot and full-scale systems should be operated until respiration rates approach background rates. We recommend that confirmatory soil sampling be conducted 4-6 months after background respiration rates are approached.

Because this is a streamlined test and evaluation project, our contract does not provide for additional reports to the base on pilot study results. The interim results report dated August 1993 contains as-builts and initial data. This letter summarizes all data collected and provides next step recommendations. AFCEE is no longer responsible for the operation, maintenance, or monitoring of the above bioventing systems. We are initiating a project to extend monitoring at some sites beyond the initial one-year test. Monitoring will include soil gas and respiration tests to document hydrocarbon degradation, but will also include the collection of sufficient final soil samples to statistically demonstrate site cleanup. AFCEE recommends continued operation of all bioventing systems. If you are interested, please call us.

The blower and accessories are now base property and should continue to be used on this or other bioventing sites. Although current equipment is explosion proof, under no circumstances should it be used for soil vapor extraction unless appropriate explosion-proof wiring is provided. If the base does not want to keep the blower or if you have further questions, please contact us at DSN 240-4331 or commercial 210-536-4331.

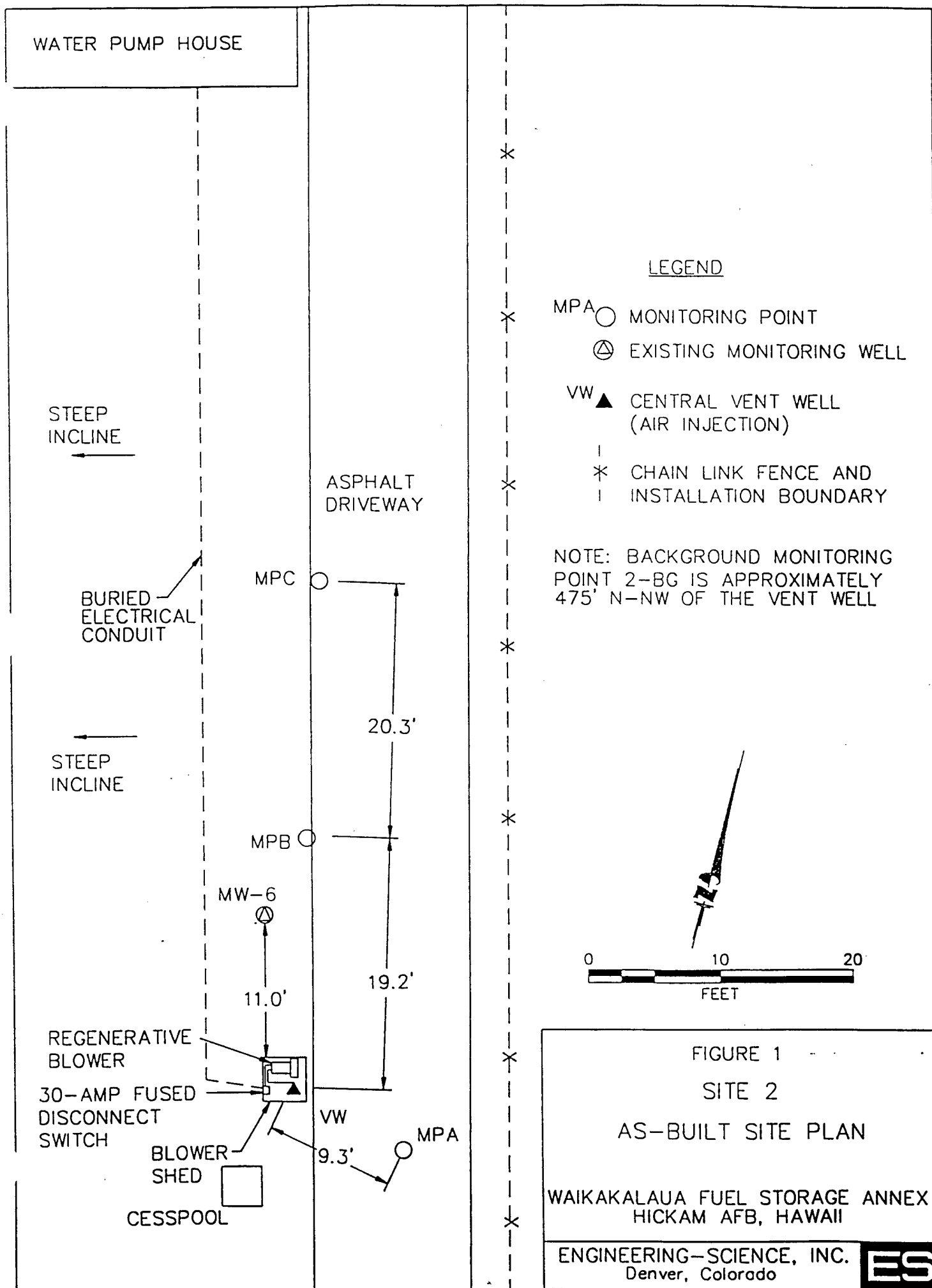
On behalf of the AFCEE/ERT staff, I would like to thank you for your support of this bioventing test and evaluation project. The information gained from each site will be invaluable in evaluating this technology and will promote its successful application on other DOD, government, and private sites. I have attached a customer satisfaction survey. Please take a few minutes to fill it out and tell us how we did. We look forward to hearing from you.

  
ROSS N. MILLER, Lt Col, USAF, BSC  
Chief, Technology Transfer Division

Attachments:

1. Waikakalaua Site 2 Data
2. Area K Data
3. Area H Data
4. Survey

cc: AFCEE/ERD (Mike McGhee)  
HQ PACAF/CEVR



**TABLE 1**  
**SITE 2**  
**RESPIRATION AND DEGRADATION RATES**  
**WAIKAKALAU FUEL STORAGE ANNEX**  
**HICKAM AFB, HAWAII**

Location - Depth (feet bgs) <sup>a/</sup>	Initial = May 1993			6 - Month <sup>c/</sup> = Nov. 1993			1 - Year = May 1994		
	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year) <sup>b/</sup>	Soil Temperature (°C)	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.0040	350	NS <sup>d/</sup>	0.00036	20	NS	0.0025	110	NS
MPA - 12.4	NS	NS	22.4	NS	NS	25.4	NS	NS	26.4
MPA - 24.3	0.017	890	NS	0.013	1600	NS	0.011	2300	NS
MPA - 70	NS	NS	26.2	NS	NS	25.1	NS	NS	25.6
MPB - 36.1	0.0010	<10 <sup>e/</sup>	NS	NS	NS	NS	0.0018	100	NS
MPC - 73.2	NS	NS	NS	0.00018	<10	NS	NS	NS	NS
MW - 6	0.018	1130	NS	NS	NS	NS	0.020	1600	NS

<sup>a/</sup> feet bgs = feet below ground surface.

<sup>b/</sup> Milligrams of hydrocarbons per kilogram of soil per year.

<sup>c/</sup> Assumes moisture content of the soil is an average between the initial and final readings.

<sup>d/</sup> NS = not sampled.

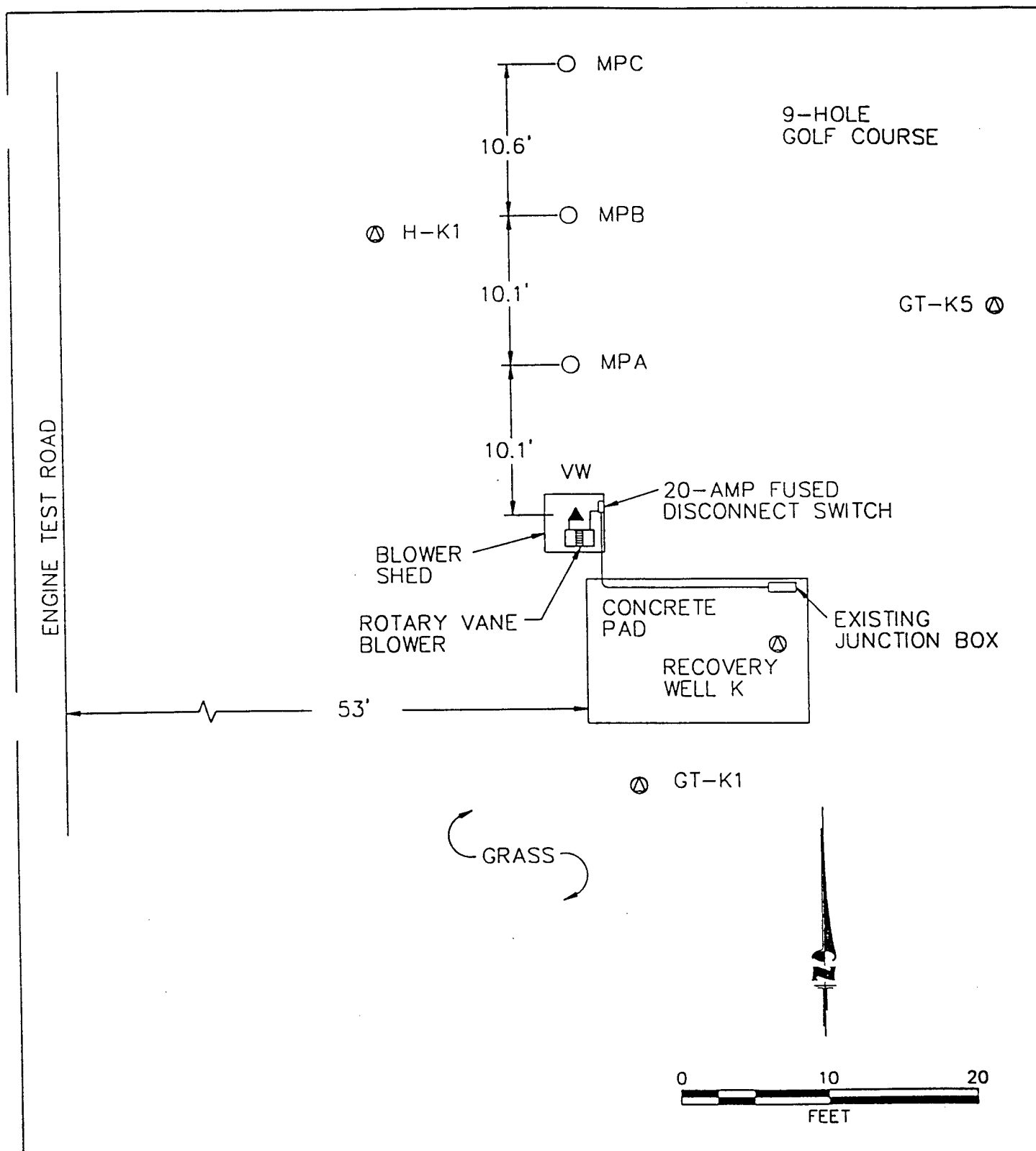
<sup>e/</sup> Although oxygen utilization was measured in these points, high levels of moisture are reducing the air - filled porosity of the soil and limiting oxygen supply to soil bacteria.

TABLE 2  
SITE 2  
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS  
WAIKAKALAU FUEL STORAGE ANNEX  
HICKAM AFB, HAWAII

Analyte (Units) <sup>a/</sup>	Sample Location - Depth (feet below ground surface)							
	VW		MPA - 24.3		MPA - 37.6			
	Initial <sup>b/</sup>	1 - Year <sup>d/</sup>	Initial	1 - Year <sup>d/</sup>	Initial	1 - Year	Initial	1 - Year
Soil Gas Hydrocarbons								
TVH (ppmv)	19,000	1.9	22,000	16,000	250	3,200		
Benzene (ppmv)	46	<0.005	<1.1	<0.26	0.083	<0.11		
Toluene (ppmv)	86	<0.005	<1.1	<0.26	0.450	<0.11		
Ethylbenzene (ppmv)	16	<0.005	21	17	0.180	5.3		
Xylenes (ppmv)	52	0.017	66	44	0.580	11		
Soil Hydrocarbons								
	VW - 29.5		VW - 60		MPA - 40		MPB - 50	
	Initial <sup>c/</sup>	1 - Year <sup>d/</sup>	Initial	1 - Year <sup>d/</sup>	Initial	1 - Year <sup>d/</sup>	Initial	1 - Year
TRPH (mg/kg)	51.76	3,540	3,586	135	553.1	1,842	43.51	<7.5
Benzene (mg/kg)	<0.52	<3.9	1.7	1.5	<0.54	0.28	0.42	0.0042
Toluene (mg/kg)	5.1	<3.9	3.6	10.7	4.5	1.3	29	0.035
Ethylbenzene (mg/kg)	8.1	33	0.85	5.3	6.5	4.7	14	0.019
Xylenes (mg/kg)	40	<5.5	4.1	26.6	31	20	77	0.049
Moisture (%)	32.6	36.6	33.4	32.5	34.8	24.3	38.5	33.9

- <sup>a/</sup>TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume;  
TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram.  
<sup>b/</sup>Initial soil gas samples collected on April 27, 1993.  
<sup>c/</sup>1 - Year soil gas samples collected on May 26, 1994.  
<sup>d/</sup>Results averaged with duplicate sample.  
<sup>e/</sup>Initial soil samples collected on March 30 to April 15, 1993.  
<sup>f/</sup>1 - Year soil samples collected on June 1 to 3, 1994.





- LEGEND
- ⊙ EXISTING WELLS
  - VW ▲ CENTRAL VENT WELL (AIR INJECTION)
  - MPA ○ MONITORING POINT

FIGURE 1  
AREA K  
AS-BUILT SITE PLAN

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.  
Denver, Colorado

**ES**

**TABLE 1**  
**AREA K**  
**RESPIRATION AND DEGRADATION RATES**  
**HICKAM AFB, HAWAII**

Location - Depth (feet bgs) <sup>a/</sup>	Initial = April 1993			6 - Month <sup>c/</sup> = Nov. - Dec. 1993			1 - Year = May 1994		
	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year) <sup>b/</sup>	Soil Temperature (°C)	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
MPA-5	0.026	5000	26.1	0.0062	1100	31.8	0.0072	1400	28.5
MPB-5	0.013	1800	NS <sup>d/</sup>	0.0092	1600	NS	0.0057	1100	NS
MPC-5	0.022	3300	NS	0.0071	1300	NS	0.0063	1200	NS

<sup>a/</sup> feet bgs = feet below ground surface.

<sup>b/</sup> Milligrams of hydrocarbons per kilogram of soil per year.

<sup>c/</sup> Assumes moisture content of the soil is the average of the initial and 1-year soil moisture values.

<sup>d/</sup> NS=Not Sampled.

TABLE 2  
AREA K  
INITIAL AND 1 - YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS  
HICKAM AFB, HAWAII

Analyte (Units) <sup>a/</sup>	Sample Location - Depth (feet below ground surface)					
	VW		MPA-5		MPC-5	
	Initial <sup>b/</sup>	1 - Year <sup>d/</sup>	Initial	1 - Year	Initial	1 - Year <sup>d/</sup>
Soil Gas Hydrocarbons						
TVH (ppmv)	4,000	17	41,000	45,000	34,000	2,600
Benzene (ppmv)	3.5	<0.01	130	<0.05	120	<0.05
Toluene (ppmv)	<0.2	<0.01	<2.0	<0.05	<2.0	<0.05
Ethylbenzene (ppmv)	2.7	0.073	41	3.3	22	2.6
Xylenes (ppmv)	14	0.24	81	9.0	48	6.7
Soil Hydrocarbons						
	VW-6.5		MPA-5.5		MPB-5.5	
	Initial <sup>e/</sup>	1 - Year <sup>f/</sup>	Initial	1 - Year	Initial	1 - Year
TRPH (mg/kg)	<5.0	66	<5.0	6.5	55	69
Benzene (mg/kg)	0.54	<0.0005	<0.83	<0.0005	2.2	<0.0005
Toluene (mg/kg)	5.9	<0.0005	6.5	<0.0005	23	<0.0005
Ethylbenzene (mg/kg)	2.6	<0.0005	6.4	<0.0005	21	<0.0005
Xylenes (mg/kg)	13	<0.0007	12	<0.0008	32	<0.0008
Moisture (%)	15.1	11.8	15.9	14.5	15.4	14.7

<sup>a/</sup>TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume;

TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram.

<sup>b/</sup>Initial soil gas samples collected on April 2, 1993.

<sup>c/</sup>1 - Year soil gas samples collected on May 23, 1994.

<sup>d/</sup>Results averaged with duplicate sample.

<sup>e/</sup>Initial soil samples collected on March 24 - 25, 1993.

<sup>f/</sup>1 - Year soil samples collected on May 31, 1994.

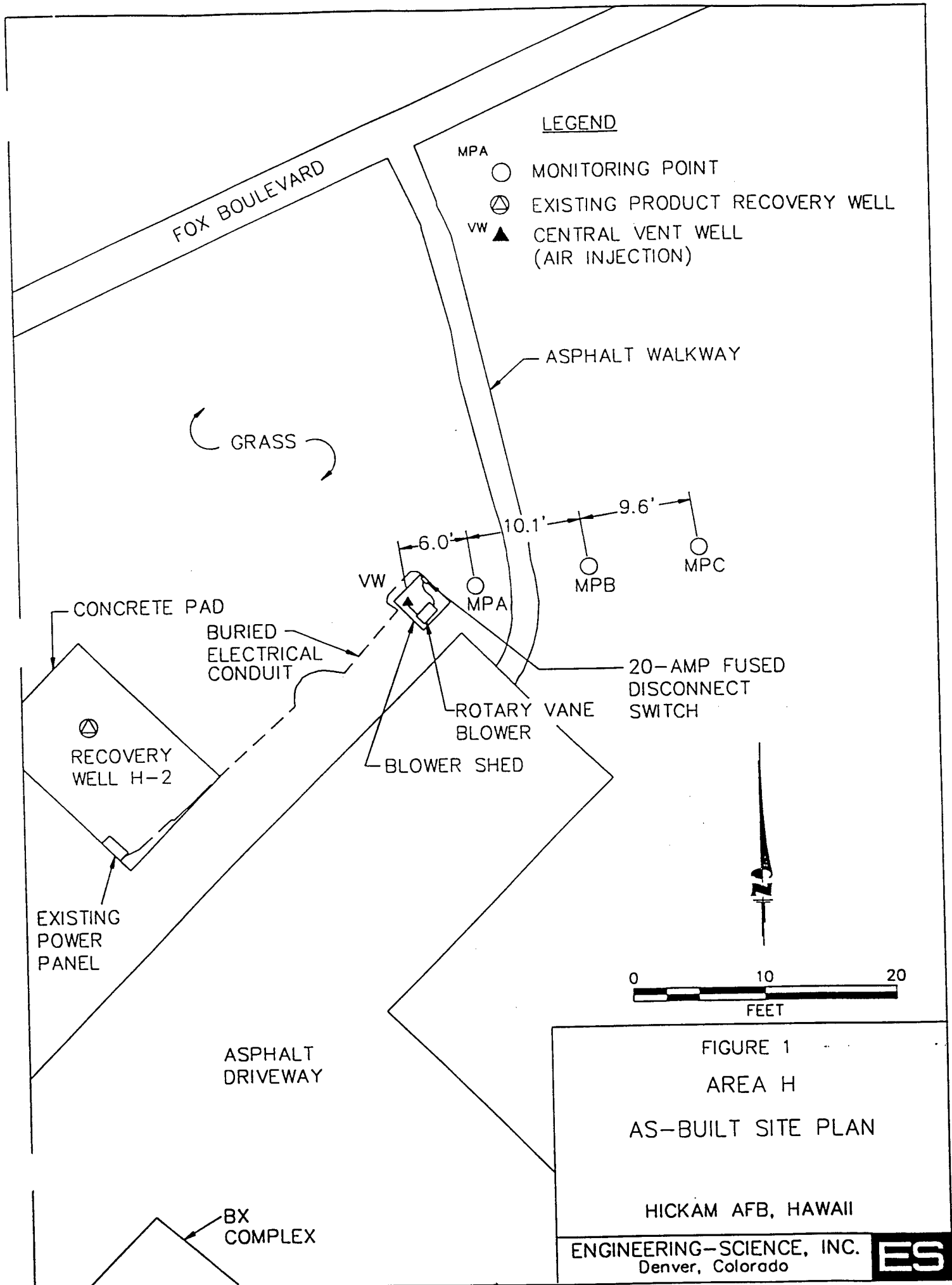


FIGURE 1  
AREA H  
AS-BUILT SITE PLAN

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.  
Denver, Colorado



**TABLE 1**  
**AREA H**  
**RESPIRATION AND DEGRADATION RATES**  
**HICKAM AFB, HAWAII**

Location - Depth (feet bgs) <sup>a/</sup>	Initial = April 1993			6 - Month <sup>c/</sup> = Nov. - Dec. 1993			1 - Year = May 1994		
	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year) <sup>b/</sup>	Soil Temperature (°C)	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K <sub>o</sub> (% O <sub>2</sub> /min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.020	<10 <sup>d/</sup>	NS <sup>d/</sup>	0.00032	<10	NS	0.00023	<10	NS
MPA - 6	0.0043	210	26.7	0.00011	<10	32.0	0.00023	<10	28.6
MPA - 12.3	NS	NS	NS	0.00046	19	NS	0.00030	<10	NS
MPA - 16.5	NS	NS	26.3	0.0031	120	28.6	NS	NS	27.3
MPB - 6.3	NS	NS	NS	0.000064	<10	NS	0.000031	<10	NS
MPB - 16.5	NS	NS	NS	0.0052	52	NS	NS	NS	NS
MPC - 12.4	0.011	110	NS	NS	NS	NS	NS	NS	NS

<sup>a/</sup> feet bgs = feet below ground surface.

<sup>b/</sup> Milligrams of hydrocarbons per kilogram of soil per year.

<sup>c/</sup> Assumes moisture content of the soil is an average between the initial and final readings.

<sup>d/</sup> NS = Not sampled.

<sup>e/</sup> Although oxygen utilization was measured in these points, high levels of soil moisture are reducing the air-filled porosity of the soil and limiting oxygen supply to soil bacteria.

TABLE 2  
AREA H  
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS  
HICKAM AFB, HAWAII

Analyte (Units) <sup>a/</sup>	Sample Location-Depth (feet below ground surface)							
	VW		MPA-6		MPB-6.3		MPC-12.4	
	Initial <sup>b/</sup>	1-Year <sup>c/</sup>	Initial	1-Year	Initial	1-Year	Initial	1-Year <sup>c/</sup>
<b>Soil Gas Hydrocarbons</b>								
TVH (ppmv)	330,000	210	2,100	6.9	NS <sup>d/</sup>	1.2	380,000	NS
Benzene (ppmv)	<10	<0.003	<0.10	<0.002	NS	<0.002	<10	NS
Toluene (ppmv)	<10	0.020	<0.10	<0.002	NS	<0.002	<10	NS
Ethylbenzene (ppmv)	26	0.018	0.15	<0.002	NS	<0.002	57	NS
Xylenes (ppmv)	<10	0.014	0.11	<0.002	NS	<0.002	61	NS
<b>Soil Hydrocarbons</b>								
	VW-18		MPA-18		MPB-18			
	Initial <sup>b/</sup>	1-Year <sup>g/</sup>	Initial	1-Year	Initial	1-Year		
TRPH (mg/kg)	<5	<6.7	23.9	7.7	9.0	<6.5		
Benzene (mg/kg)	2.25	0.06	<0.22	0.043	6.0	0.13		
Toluene (mg/kg)	8.7	0.0014	1.2	0.032	6.0	0.0063		
Ethylbenzene (mg/kg)	6.3	0.0014	2.0	0.0069	8.1	0.0064		
Xylenes (mg/kg)	16.0	0.001	2.6	0.0099	4.0	0.0028		
Moisture (%)	25.3	25.2	22.2	23.8	26.4	23.2		

<sup>a/</sup>TVH= total volatile hydrocarbons; ppmv=parts per million, volume per volume;

TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram.

<sup>b/</sup>Initial soil gas samples collected on April 22, 1993.

<sup>c/</sup>1-Year soil gas samples collected on May 18 and 21, 1994.

<sup>d/</sup>NS = not sampled.

<sup>e/</sup>Sample could not be collected due to presence of water at the screen.

<sup>f/</sup>Initial soil samples collected on March 23 and 24, 1993.

<sup>g/</sup>1-Year soil samples collected on May 31 and June 1, 1994.